SDH solar district heating

Success Factors in Solar District Heating

by

CIT Energy Management AB

This project is supported by:

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Success Factors in Solar District Heating

WP2 - Micro Analyses Report

Deliverable D2.1

December 2010

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SUMMARY

District heating and solar heating has got increased interest all over Europe in recent years and more than solar 100 plants with more than 500 m² of solar collectors have been put into operation since the mid 90's.

A number of interesting applications of solar heat, i.e. in combination with CHP, provided by ESCO's, using net-metering, using innovative seasonal storage and solar heating and cooling concepts, are described and analysed in order to enhance knowledge and technology transfer. A prevailing success factor is the involvement of one or several local actors with interest and knowledge to develop and demonstrate the new technologies, being a local city government, a local utility, a local manufacturer or a combination of those.

A combination of favourable conditions and strong local actors has created a boom for large solar district heating plants in Denmark. The recent strong development in Wind Power in Denmark has created a situation where it in periods with good wind conditions is less feasible to operate the CHP and more feasible to operate boilers to supply the required district heat. This situation makes solar district heating very interesting.

A strong local actor has succeeded to introduce solar district heating on a large scale in the city of Graz, Austria. The anticipated uncertainties with solar heating has been overcome by the creation of an Energy Service Company (ESCO) that makes the investment, operates the plant and sells the heat to housing facility owners and/or to the district heating utility. An increased interest by building owners connected to district heating has further created a strong development of small distributed solar heating systems with net-metering contracts in Swedish district heating systems.

Furthermore, a number of applications to combat and utilise the annual variations of the solar radiation have been demonstrated. First, a number of innovative seasonal storage concepts in Germany, second, the use of solar heat to provide cooling, e.g. in Czech Republic.

Key words:
Solar heating, district heating, solar cooling

SDH solar district heating

CONTENT

INTRODUCTION

District heating and solar heating has got increased interest all over Europe in recent years. Block and district heating is one major approach to increase the overall energy efficiency in urban areas, either by refurbishment of existing systems or by the introduction of new system in existing or new building establishments. Solar heat is available in principle anywhere all over Europe. The development is supported by increased incentives in the form of EG directives, local and regional support policies together with improved competiveness in the local heating markets.

The result is that more than 100 plants with more than 500 m² of solar collectors have been put into operation since the mid 90's. Out of these about 40 plants have a nominal thermal power of 1 MW and a major part of the plants are connected in existing or new block and district heating schemes.

Some interesting examples are described shortly in the following section about **SUCCESS STORIES**. The next section describes **TECHNOLOGIES AND APPLICATIONS** more in detail. The section **SYSTEM TYPOLOGY** shows the basic solar district heating system schematics and the last section **HISTORICAL DEVELOPMENT** gives an overview of the installations from 1979 to 2009.

Furthermore, the **APPENDICES** include contacts, descriptions, histories, costs, as well as lessons learned and recommendations, for 8 sample solar (district) heating plants.

SUCCESS STORIES

A prevailing success factor is the involvement of one or several local actors with interest and knowledge to develop and demonstrate the new technologies, being a local city government, a local utility, a local manufacturer or a combination of those.

Solar heat in CHP plants in Denmark

Fossil based Combined Heat and Power (CHP) dominates electricity generation and the heat supply in urban areas, in Denmark as in several other European countries. The recent strong development in Wind Power in Denmark has created a situation where it in periods with good wind conditions is less feasible to operate the CHP and more feasible to operate boilers to supply the required district heat.

The above condition makes it feasible to introduce short-term storages in the district heating plants, as it facilitates the capabilities to adopt the plant operation to the electricity price with less boiler operation. Relatively high district heat costs and a strong local solar collector industry have then created opportunities to introduce large solar heating plants in connection to existing or new short-term storages in CHP plants. Other important aspects are the governmental requirements to reduce the fossil heat supply and increase the share of renewable heat in district heating.

Fig. 1: Solar district heating plant in Brædstrup, Denmark.

The local manufacturer ARCON pioneered solar heat in district heating in the late 1980’s together with a couple of small utilities. A major breakthrough was the development of a number of solar district heating plants initiated by Marstal Fjernvarme in the late 1990's. The recent development is initiated by Brædstrup Fjernvarme and followed by several district heating utilities in cooperation with Dansk Fjernvarme (Danish District Heating Association).

Fig. 2: Solar district heating plant in Strandby, Denmark.

The above described development has resulted in seven new plants with solar collector arrays from 5 000 to 10 000 m^2 (3.5-7 MW_{th} nominal power) put into operation since 2006 and several more are planned.

More detailed descriptions of the development of the solar district heating plants in Brædstrup (Fig. 1) and Strandby (Fig. 2), Denmark, can be found in Appendix 1 and 2. Solar heat costs are of the order of 4 Eurocent/kWh without subsidies (annuity 0.064). Lessons learned are related to call for and evaluation of tenders, a careful design of collector system pipes in ground (taking into account larger temperature variations than in typical district heating networks) and the importance of developing an appropriate control system.

ESCO develops solar heat in Austria

The implementation of solar heating requires a major investment while the operation costs are very low. One prerequisite to make the investment is that the plant owner judges the risk in a favourable way. As most utilities and building owners lack experience from solar heating the risk is judged to be too large, even if the long term economic feasibility looks interesting. One way to overcome this problem is to create an Energy Service Company (ESCO) that makes the investment, operates the plant and sells the heat to a housing facility owner or to a district heating utility.

The main driver behind the solar ESCO development is the local company S.O.L.I.D. The development has led to a number of realised solar heating plants in Austria, especially four large plants in the district heating system in Graz.

Fig. 3: Solar district heating plant at Berliner Ring in Graz, AT.

More detailed descriptions of the developments of the solar district heating plants at Berliner Ring (Fig. 3) and Wasserwerk Andritz, can be found in Appendix 3 and 4. Solar heat costs are of the order of 6-8 Eurocent/kWh without subsidies (annuity 0.064). Lessons learned are about the need for a careful design (of the connection to the district heating network), as well as that devoted and experienced project partners are important prerequisites to reach a common goal.

Demonstration of BTES in Germany

A major challenge to increase the potential use of solar heat is the possibility to store heat from the summer to the heating season and thus be able to cover a larger part of typical loads in district heating systems. Four different types of seasonal storage, TTES, PTES, BTES and ATES (Fig. 4), are now demonstrated in Germany since a decade

The main driver is a comprehensive national R&D program "Solarthermie" carried out by a number of experienced actors exchanging their knowledge in a national expert's network called "Arbeitskreis Langzeit-Wärmespeicher" (www.saisonalspeicher.de). The goal is to achieve a market introduction of the first storage types by 2020. [2]

BTES has now been successfully demonstrated in two plants, the first plant in the new Neckarsulm-Amorbach area has been in operation since 1997 and a second plant in a refurbishment project in Crailsheim was put into operation in 2008. Both plants cover about 50% of the total annual heat load in connected buildings.

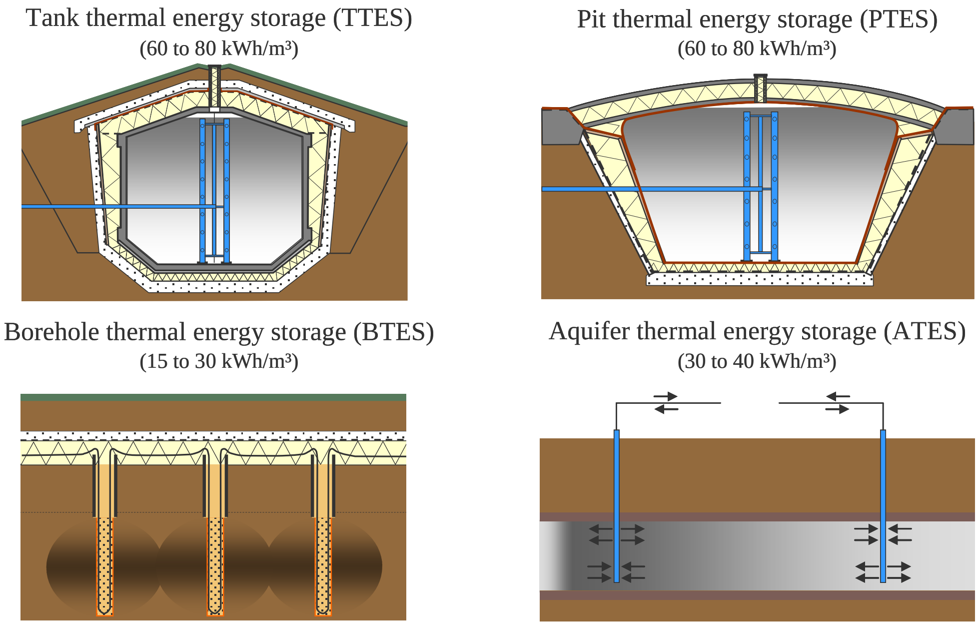

Fig. 4: Main four concepts for seasonal thermal energy storage (Source: Solites).

More detailed descriptions of the developments of the solar district heating plants in Neckarsulm-Amorbach and Crailsheim, can be found in Appendix 5 and 6. Lessons learned are related to the appropriate integration of solar collectors on buildings, the detailed design and construction of the BTES, as well as the improvements related to the utilisation of a heat pump in connection to the BTES.

Net-metering of solar heat in Sweden

An increased number of building owners connected to district heating have expressed an interest to use solar collectors on their buildings. A common alternative is to design a solar heating system with a local diurnal storage to preheat hot water in the actual building and make up the deficit with the existing district heating. Another often much simpler alternative is to connect the solar heating system in the district heating main circuit, use the district heating system as buffer storage and develop a net-metering contract with the district heating provider. See the last section SYSTEM TYPOLOGY for more information.

The development was pioneered by the municipal service building's owner and the district heating provider in Malmö (E.ON, former Sydkraft) and has now resulted in a number of systems in other cities. The development of a prefabricated solar district heating sub-station (Fig. 5) in co-operation with an established system component company has been a major facilitator in this development as it provides common boundary conditions for the systems.

Fig. 5: Pre-fabricated solar district heating sub-station.

A detailed description of the development of the solar district heating plant in Vislanda, can be found in Appendix 7. Solar heat cost is of the order of 7 Eurocent/kWh without subsidies (annuity 0.064). Lessons learned are related to the appropriate design of the connection to the existing district network (pressure, temperatures, etc.) and the development of net-metering contracts.

Solar Cooling in Czech Republic

The possibility to combine solar heating and cooling with an absorption (and adsorption) chiller has a great potential in district heating and cooling systems. The collector yield is in phase with the cooling load and it is possible to utilize the waste heat. A more detailed description of the development of the solar cooling plant on Hotel DUO in Prag (Fig. 6) can be found in Appendix 8.

Fig. 6: View of Hotel Duo with solar cooling plant on roof top.

Solar heat cost is of the order of 8 Eurocent/kWh without subsidies (annuity 0.064). The system includes standard components and the main lessons learned are about the importance of developing an appropriate control system.

Positive cost perspectives

There are still not a lot of solar district heating systems, but the Danish investment costs are already now on a very interesting level with resulting solar heat costs in the range of 4 Eurocent/kWh excluding subsidies (annuity 0.064). The Danish plants are rather simple with large ground mounted collector arrays built by utilities in connection to existing heating plants based on experiences from previous similar plants.

The Austrian plants include collectors mounted on ground, as well as on roofs, built in connection to existing district heating systems by an ESCO. The solar heat costs in the Austrian plants are not far from the Danish and will decrease further by an increased demand for this type of applications.

The explicit solar heat cost in the German plants are rather high due to the more advanced integration of solar collectors on buildings, a completely new infrastructure and the demonstration of seasonal storage, but cover in turn a much larger part of the heat load (i.e. they introduce a larger reduction of fossil based heat supply).

The investment costs for large collector arrays are rather similar, but the success stories include different applications in different development phases and the total investment costs, as well as the amount of subsidies required, are thereby different. However, the present policies are moving towards stronger restrictions on fossil based heating and support for renewable heat options. Here the main alternatives are biomass, geothermal heat and solar heat, and it is only solar heat that can present about the same potential contribution all over Europe. An increased interest and demand for solar district heating with more frequent call for tenders for larger systems will introduce more actors (established as well as new) and more competition, thus lowering the investment costs to acceptable levels for a large number of applications.

APPLICATIONS AND TECHNOLOGIES

The majority of the large-scale plants supply heat to residential buildings in block and district heating systems. Typical operating temperatures range from low 30°C to high around 100°C (water storage). Two thirds of these plants are connected to existing buildings, especially in Sweden, Denmark and Austria. A large part of the plants in Sweden and Austria are built in connection to wood fuel fired heating plants. Non-residential plants are e.g. installed in industries and commercial buildings. The largest plants are listed in Tables 1, 2 and 3.

Table 1: The largest solar heating plants with ground-mounted collector arrays in existing and some new block and district heating systems (Feb. 2010).

Plant location, Year in operation, Country	**Coll.area** [m²]	**Nom.power** [MW_{th}]	**Heat** [GWh/a]	**Plant type**	**Load** [GWh/a]
Marstal, 1996, DK	18 300	12.8	8.5	B / Bio-oil	28
Broager, 2009, DK	10 700	7.5	4.5	CHP / NG	24
Gram, 2009, DK	10 073	7.0	4.5	CHP / NG	28
Kungälv, 2000, SE	10 000	7.0	3.9	B / Wood chips	100
Brædstrup, 2007, DK	8 012	5.6	3.4	CHP / NG	42
Strandby, 2008, DK	8 012	5.6	3.5	CHP / NG	21
Tørring, 2009, DK	7 284	5.1	3.4*	CHP / NG	28
Sønderborg, 2008, DK	5 866	4.1	2.6*	B / Bio-oil	n.a.
Ulsted, 2006, DK	5 000	3.5	2.2	B / WP	11
Ærøskøping, 1998, DK	4 900	3.4	2.0	B / Straw	14
Graz, Ww Andritz, 2009, AT	3 855	2.7	1.6	(DH)	(0.8)

Legend: B = Boiler; CHP = Combined Heat and Power; DH = District Heat; WP = Wood pellet; *Calculated

Table 2: The largest solar heating plants with roof-mounted collector arrays in new and some existing block and district heating systems (Feb. 2010).

Plant location, Year in operation, Country	**Coll.area** [m²]	**Nom.power** [MW_{th}]	**Heat** [GWh/a]	**Plant type**	**Load** [GWh/a]
Crailsheim, 2005, DE	7 300	5.1	2.1	BTES / HP	4.1
Neckarsulm, 1997, DE	5 670	4.0	1.5	BTES / HP	3.0
Graz, AEVG, 2006, AT	5 600	4.0	2.2	(DH)	(n.a.)
Friedrichshafen, 1996, DE	4 050	2.8	1.4	Buried CWT	3.0
Hamburg; 1996, DE	3 000	2.1	0.8	Buried CWT	1.6
Schalkwijk, 2002, NL	2 900	2.0	n.a.	Aquifer / HP	n.a
München, 2007, DE	2 900	2.0	1.1	Buried CWT / HP	2.3
Graz, BerlinerRing, 2004, AT	2 417	1.7	1.0	(HP/DH)	(7.8)
Anneberg, 2002, SE	2 400	1.7	0.5	BTES	1.0
Augsburg, 1998, DE	2 000	1.4	0.7	BTES	1.0

Legend: Heat = Net solar heat; BTES = Borehole Thermal Energy Storage; HP = Heat Pump; CWT = Concrete water tank; DH = District Heat

Most of the plants have roof-integrated or roof-mounted solar collectors while 22 plants in Sweden and Denmark have ground-mounted collector arrays. More than 80% of the plants are equipped with flat plate collectors, mostly large-module collector designs. In a couple of cases in Sweden and Germany roof-mounted collectors are designed as more or less complete roof modules. Most plants have pressurised collector systems with an anti-freeze mixture; usually glycol and water, while four plants in the Netherlands have drain back collector systems.

Table 3: The largest solar heating and cooling plants in misc. applications (Feb. 2010).

Plant, Year in operation, Country	**Coll.area** [m²]	**Nom.power** [MW_{th}]		**Application**	
Sarantis S.A., 1998, GR	2 700	1.9		Industry/Cooling	
Van Melle, 1997, NL	2 400	1.7		Industry/Heat	
CGD / Lisbon, 2007, PT	1 620	1.1		Office/Cooling	
Inditex, 2003, ES	1 500	1.0		Industry/Cooling	
D&W / Lisse, 1995, NL	1 200	0.8		Industry/Heat	
Tyras S.A., 1999, GR	1 040	0.7		Industry/Heat	

The majority of the plants are designed to cover the summer heat load - i.e. hot water and heat distribution losses - using diurnal water storages, but 20 plants are equipped with seasonal storages and cover a larger part of the load. The seasonal storages comprise water in insulated tanks (above or in ground) in ten plants, the ground itself in seven, aquifers in two and a combination of ground and water in one plant. Ten plants are designed to cover the summer cooling load in heat driven cooling applications.

District Heating

The Swedish large-scale solar heating plants are used by district heating and housing companies, mainly for existing building areas, using both ground mounted collector arrays and roof-integrated or mounted collectors. The oldest plant still in operation dates from 1985.

Fig. 7: Solar district heating plant in Kungälv, SE.

The largest so far is a plant with 10 000 m² ground-mounted collector array built by Kungälv Energi AB as a complement to an existing wood-chips boiler plant (Fig. 7). The plant yields close to 4 GWh/a out of a total load of about 100 GWh/a (Table 1).

Recent developments comprise decentralised solar systems connected to the primary district heating networks in a number of cities, e.g. Malmö.

The Danish large-scale solar heating plants are used in small district heating systems and all collectors are ground mounted. Based on Swedish experiences the first Danish plant, with 1 000 m² of ground-mounted collectors, was built in Saltum 1987.

Fig. 8: Solar district heating plant in Marstal, DK.

In 1995 Marstal Fjernvarme A.m.b.a. decided to establish about 8 000 m^2 solar collectors and a 2 100 m^3 water storage tank to cover up to 15% of their heating load. The Marstal plant was extended to 18 300 m^2 (12.8 MWth) and is so far the largest solar heating plant in Europe (Fig. 8). A study of the potential for solar district heating in Denmark has resulted in seven new plants 2006-2009 and more to come.

Block Heating

The Swedish housing company EKSTA Bostads AB pioneered the use of roof-integrated solar collectors in new building areas already in the 80's. At present EKSTA owns and operates about 7 000 m² of roof-integrated collectors. Initially EKSTA used site-built collectors, but the latest development, a roof module collector mounted directly on the roof trusses, has now been applied in a couple of recent projects in new, as well as on, existing buildings. This development has resulted in even better integration in the building process, as well as further reduced investment cost and improved thermal performance.

The German large-scale solar heating plants are mainly applied in new residential building areas using roof-integrated or mounted collectors. Some of the large projects have so called “solar roofs”. Until 2003 eight projects with seasonal storage, and about 50 large- to medium-scale projects with short-term storage, had been realised within the Solarthermie2000 programme. There are e.g. two plants with >5 000 m² of roof-integrated collectors in Neckarsulm-Amorbach (Fig. 9) and Crailsheim and a rather new plant with 2 900 m² in Munich.

Fig. 9: Solar block heating in Neckarsulm, DE.

The first large-scale solar plant in Austria – a small local biomass-fired heating plant complemented with a solar system - was built in Deutsch-Tschantschendorf in 1995. Graz is now the large-scale solar city of Austria with the first plant built in 2002 and two new plants, the largest one with >5 000 m² solar collectors on AEVG connected to the district heating network (Fig. 10).

Fig. 10: Solar district heating plant on AEVG, Graz, Austria.

The most widely implemented application of large solar heating systems in The Netherlands is collective housing, institutions and homes for the elderly. Most systems have about 100 m² of solar collectors, but some are larger, for example the "Brandaris" building in Amsterdam with 700 m² of rooftop mounted collectors. Two large-scale plants are designed with seasonal storage, one is a recent plant with 2 900 m² of solar collectors connected to an aquifer storage in Schalkwijk. There are further a couple of solar block heating plants in France, Switzerland and Poland.

Other Applications

A couple of the large solar systems in the Netherlands and Greece are industrial heat applications, e.g. a plant with 2 400 m² of flat plate collectors on the Van Melle industry in Breda, The Netherlands.

The first large-scale solar cooling plant - 2 700 m² of flat plate collectors providing heat to two adsorption chillers (2 x 350 kW) – was installed in Athens, Greece in 1998. The other solar cooling plants are equipped with absorption machines (LiBr).

Fig. 11: Solar collectors on the CGD building in Lisbon, Portugal.

At present there are also a couple of recent large-scale solar cooling plants in Italy, Spain and Portugal, e.g. a plant with 1 579 m² of solar collectors on top of the largest bank in Portugal, Caixa Geral de Depósitos (CGD), in Lisbon (Fig. 11).

SYSTEM TYPOLOGY

District heating is an infrastructure where heat is distributed in under (or above) ground pipe networks by circulating heated water. The water delivers heat in sub stations in connected buildings and is returned to the main heating plant where it is heated again. See Fig. 12.

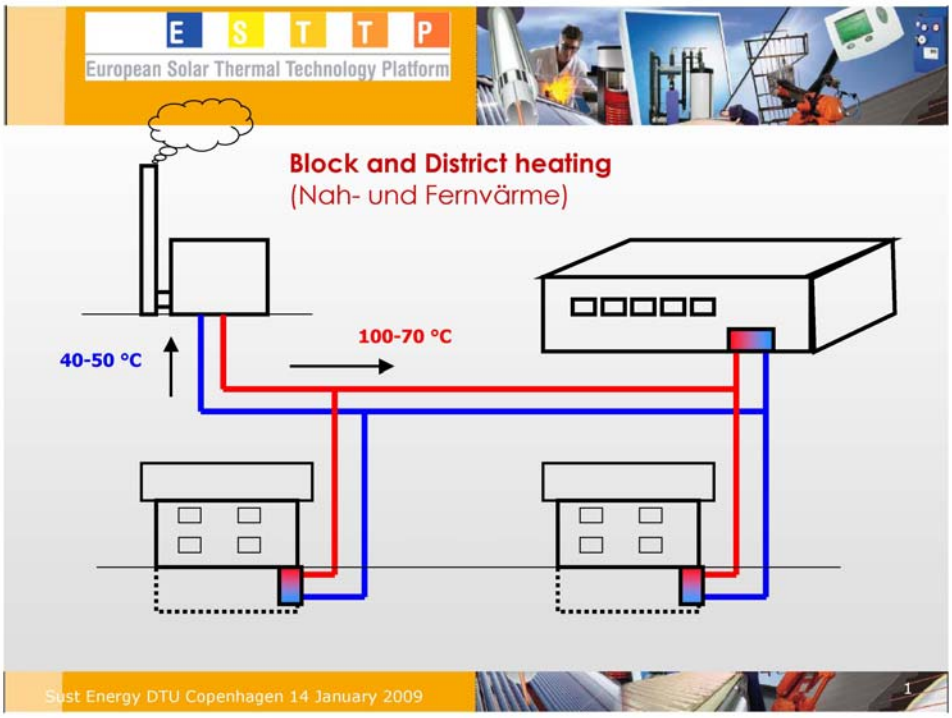

Fig. 12: District heating system

The initial solar district heating plants were all of the type where the collector array and the storage were erected in close connection to and connected to a main heating plant. See Fig. 13. The solar collectors can be mounted on ground or on roofs. The plant is owned and operated by a district heating provider (local utility, housing owner, etc.). All plants in Table 1 and 2 except the Austrian plants are of this type.

A number of recent plants have instead been erected where there is a suitable location for the collector array (on the ground or on a roof) and connected directly to the district heating primary circuit on site. See Fig 14. Austrian plants in Table 1 and 2 plus a number of Swedish plants are of this type. Here there are three owner options, the housing facility owner, a specific plant owner (ESCO) or the utility.

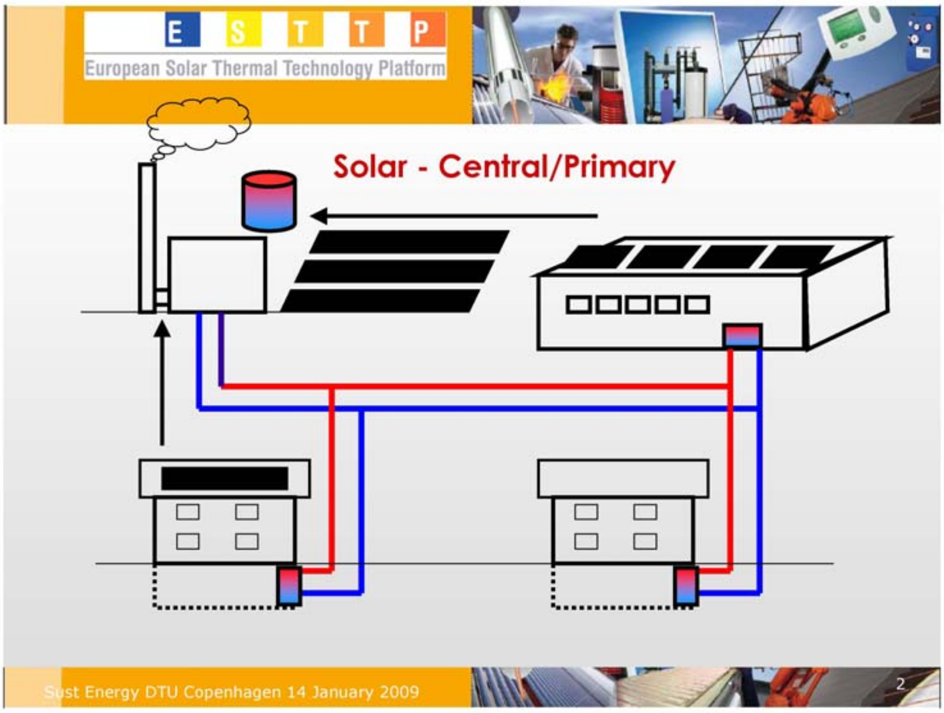

Fig. 13: Central solar district heating plant

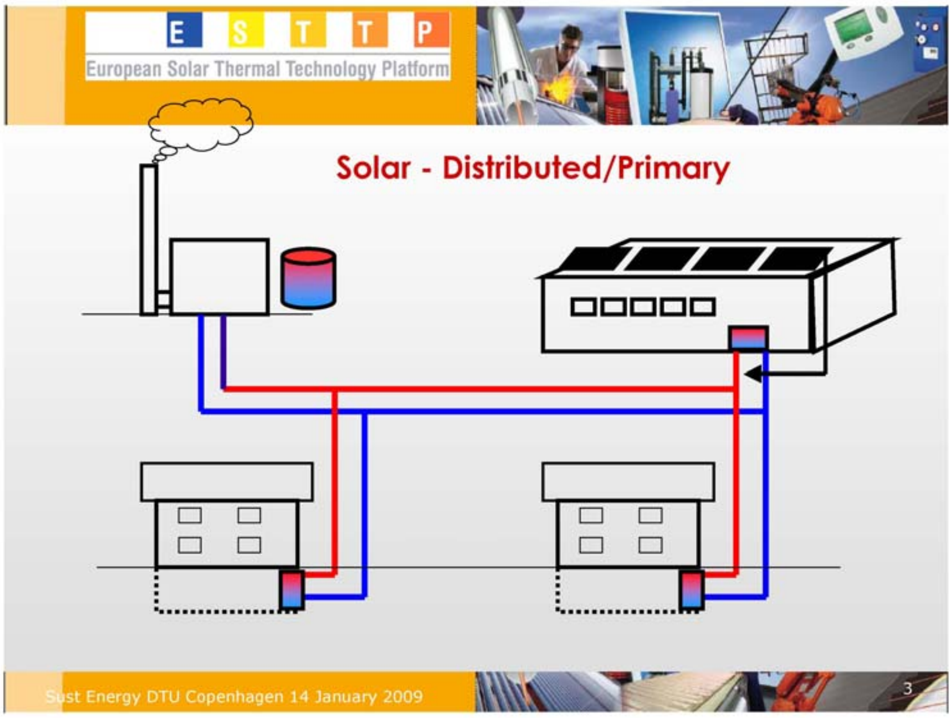

Fig. 14: Distributed solar heating plant

The distributed plants are in principle operated on their own and are commonly designed based on the available space and the existing dimensions of the district heating branch on site, not the actual load in a specific building. The majority of these plants have no storage as they can utilise the district heating network as storage (as long as they provide a small amount of heat in comparison to the total load in the district heating system). Fig. 15 shows system schematics for a distributed solar district heating plant connected to the primary circuit in a multi-family building.

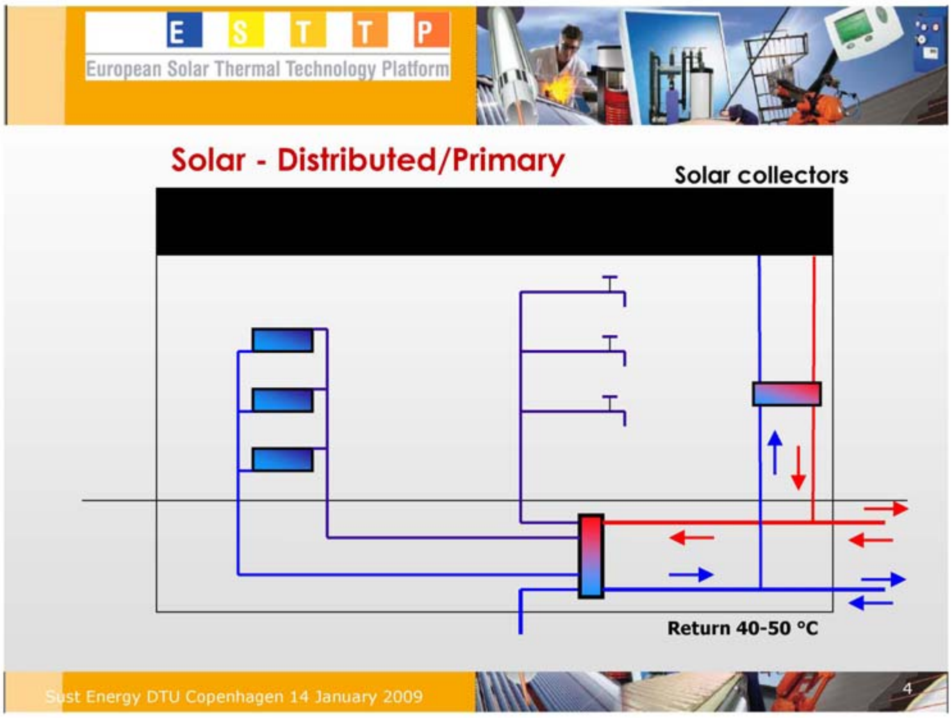

Fig. 15: Distributed solar heating plant substation.

Initially there were also a number of plants erected on buildings connected to block or district heating plants. In these cases the plants were commonly connected to the hot water system in the secondary circuits (left in Fig. 15) and designed for the local domestic hot water load, and district heat was used when necessary as auxiliary heat supply. These plants are commonly owned and operated by the housing owner.

HISTORICAL DEVELOPMENT

There are about 130 documented plants having more than 500 m² (~350 kW_{th}) of solar collectors. Out of these about 40 plants have a nominal design power of 1 MW_{th} or more. The total collector area of about 240 000 m² (~170 MW_{th}) in these plants corresponds to 1% of the total installations or about 60 000 SDHW systems.

Large-scale solar heating systems were introduced in the late 70's by the interest to develop solar heating systems with seasonal storage. Sweden had a leading role in the early demonstrations together with The Netherlands and Denmark. In the 90's the interest in large-scale solar heating increased in Germany and Austria and more than 100 new plants with more than 500 m² of solar collectors have been put into operation since the mid 90's. .

The present developments include mainly large-scale plants with diurnal storage for residential heating (block and district heating), but also industries and heat driven cooling applications in Southern Europe. A continued interest to develop plants with seasonal storage remains mainly in Denmark and Germany [1].

Table 4: **Large-scale solar heating and cooling plants in Europe**

Country	First	Oper.	Down	Ground	Roof	Storage
Sweden	1979	20	10	13	17	xS, DS, SS
Austria	1980	16	2	2	16	xS, DS
The Netherlands	1985	7	1		8	DS, SS
Others		6	1		7	
Greece	1986	14		1	13	DS
Denmark	1988	16		16		xS, DS, SS
Germany	1993	18	1	(2)	19	DS, SS
Switzerland	1995	7		1	6	DS, SS
Spain	1999	13		1	12	DS
France	1999	3			3	DS
Italy	2002	3			3	DS
Poland	2004	3			3	DS
Total		**126**	**15**	34	107	

Legend: SS = Seasonal Storage; DS = Diurnal Storage; xS = District Heat Network as storage

The no of plants in different countries is shown in Table 4. Sweden is still the leading country with a total of 20 plants in operation, although 10 plants, the first from 1979, have been closed after 10-20 years of operation and evaluation.

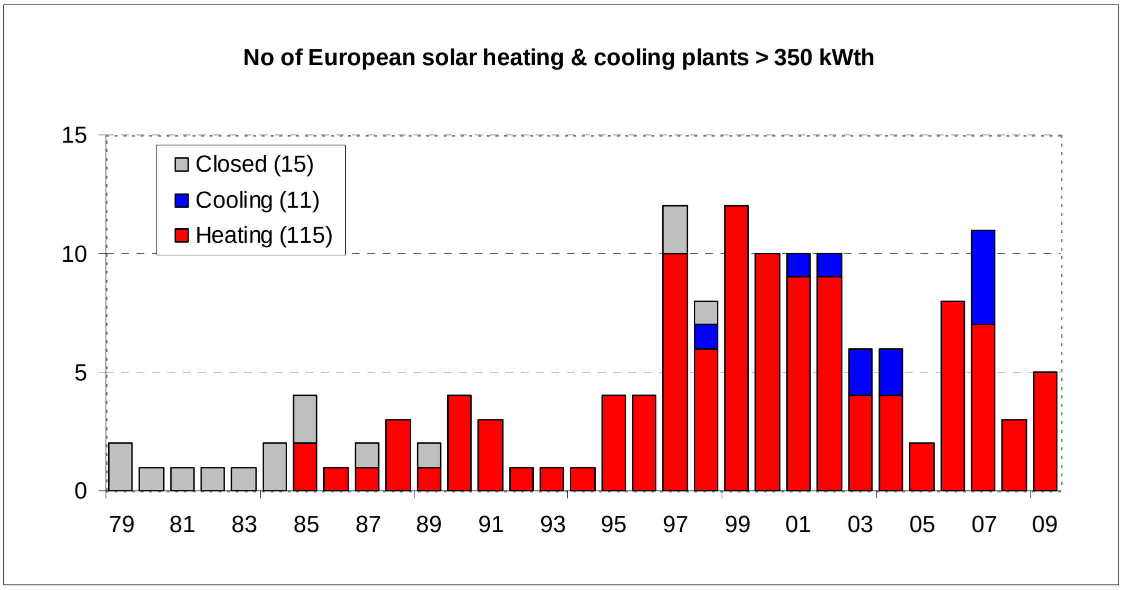

Fig. 16: No of solar heating and cooling plants with >500 m^2 of solar collector area (>350 kWth) built in Europe.

The distribution of plants related to year of commission is shown in Fig. 16. The oldest plants still in operation are from 1985 but the majority of plants have been in operation for 15 years or less. There was a negative trend in 2003-2005 and 2008-2009, but there are several large plants planned to be in operation in 2010.

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[2] Mangold, D. (2007). Seasonal Storage – A German Success Story. Sun & Wind Energy, 1/2007.

APPENDICES

Appendices A1-A8 includes contacts, descriptions, histories, costs, as well as lessons learned and recommendations, for 8 sample solar (district) heating plants.

Appendix A9 includes a comparison of cost and performance for the 8 sample plants.

A1. Brædstrup, DK – 3 pages

A2. Strandby, DK – 6 pages

A3. Berliner Ring, AT – 2 pages

A4. Wasserwerk Andritz, AT – 3 pages

A5. Neckarsulm-Amorbach, DE – 4 pages

A6. Crailsheim, DE – 4 pages

A7. Vislanda, SE – 4 pages

A8. Hotel DUO, CZ – 4 pages

A9. Cost Tables – 4 pages

A1. Brædstrup, DK

PLANT	
Name / Id	Brædstrup District Heating
Address	Fjernvarmevej 2, 8740 DK, Brædstrup
Operation	01.09.2007
Owner	Brædstrup District Heating
Contakt person Name, tel. e-mail	Per Kristensen +45 75.75.33.00 pk@braedstrup-fjernvarme.dk
Type Short description of the application	Ground Located solar plant which is operated in combination with a CHP. There is no seasonal storage systems at the time but a steel tank at 2.000 m3/110 MWh
Technical Basic data, type and dimensions, etc.	The heat load is 42 GWh/year; The collector product: ArCon Solvarme Collector area: 8.000 m2; 3.4 GWh/year Solar contribution: 8 % Storage type: Steel – 2000 m2/110 MWh
Economics Basic data, investment, subsidies, solar heat cost (describe assumptions), etc	Total investment 2007: 1.640.000 euro Subsidies: 320.000 euro Operating expenses: 660 euro/GWh solar heat
PLANT HISTORY	
Initiation Who initiated the plant and why ?	Brædstrup District Heating took the initiative The solar thermal plant in Brædstrup was the first in Denmark (perhaps in the world?) which was established in combination with a CHP. The project in Brædstrup formed school for many other plants in Denmark and there are now - either established, under construction or planned around 15 similar plants in Denmark
Support Describe possible national incentives to this type of applications	As in Denmark there are no standard subsidies for this type of installation, the incentive to establish these facilities is to ensure greater independence from mainly natural gas and to provide a well-defined environmental profile
Development How was the project developed, by whom and why ?	The project was developed and conducted to pursue Brædstrup Remove Heating goal to continue to be among the cheapest 20% decentralized CHP plants in Denmark – also in the future. Meanwhile, the project is a very important initiative in efforts to pursue a strong environmental profile.

Planning and Design Who made the planning and the design and why ?	The design and planning was made in a very closely teamwork with the suppliers in the project and the engineering companies - not at least PlanEnergi
Tendering Lessons learned ..	The solar heating system incl. heat exchanger and the connection of the solar thermal plant into the plant was in tender. The lesson learned is, that the prices was very identical.
Construction Technologies, lessons learned	The actual solar technology was further developed in connection with the project - especially since temperatures are markedly higher in interoperation with a CHP than traditionally. One of the biggest challenges in the project management was in the interaction with the engines and boilers in the plant
Commissioning Lessons learned ..	In connection with the commissioning and immediately afterwards the steering systems was a challenge.
Operation Lessons learned ..	There have been no insurmountable problems with the solar system. However, it is very important to draw attention to the enormous forces that influence pipe in the ground and caused the very large temperature differences. In this case there could be temperature increments of up to 90 degrees Celsius over a day
Performance Lessons learned ..	The current production is approx. 7% below forecast and compared to original estimates?
Lessons learned Major lessons	The overall assessment of solar thermal project at Brædstrup District Heating is, that solar thermal plant in broadly is in line with the expectations. The results are of so sufficiently good, so that the planned expansion of the solar thermal plant in the first stage is to an area of 16,000 m2 and the second stage to approx. 50,000 m2
Recommendations Major recommendations	It is recommended: - To define very clear interfaces between the individual enterpriser and lots - That the forces in the underground pipes is taken very seriously - That the guarantee provisions are negotiated as attractive as possible - That the steering systems and conditions are attached great importance

Photos	 

A2. Strandby, DK

PLANT	
Name / Id	Strandby Varmeværk
Address	Ravmarken 8, DK-9970 Strandby
Operation	From date November 2008
Owner	Strandby Varmeværk (consumer owned)
Contakt person Name, tel. e-mail	Flemming Sørensen + 45 2421 4933 kraftvarme@strandby.dk
Type Short description of the application	District heating Ground mounted Diurnal storage
Technical Basic data, type and dimensions, etc.	Heat load: 20,9 GWh / year Collectors: 8019 m2 ARCON HT flat plate collectors) Solar contribution: 3,76 GWh / year (18 %) Storage type: 2 x 1500 m^3 steel tanks
Economics Basic data, investment, subsidies, solar heat cost (describe assumptions), etc	**Investment** **1000 €** Solar collectors 1440 Pipes in solar circuit 160 1500 m3 accumulation tank 410 Heat exchanger, pumps, pipes on secondary site 130 Control system 40 Absorption cooler including piping 240 Consultancy 140 Total 2560 Subsidies 480 Total incl.. support 2080
PLANT HISTORY	
Initiation Who initiated the plant and why ?	Strandby Varmeværk initiated the plant. Flemming Sørensen participated in dissemination arrangements concerning combination of solar thermal plants and district heating with natural gas fired combined heat and power plants. Energinet.dk had during the winter 2005-06 made an investigation of the consequences for the electricity system if solar thermal plants were implemented in combination with natural gas fuelled CHP-plants. The result was that solar thermal plants could contribute in a positive way to electricity regulation.

Support Describe possible national incentives to this type of applications	As a consequence of the positive results of the above mentioned investigations Energinet.dk announced support for demonstration plants in spring 2006. Brædstrup and Strandby got support to their plants. In 2010 the only support for new solar plants is the value of energy savings from a centralised solar plant. App: 17 €/m^2.
Development How was the project developed, by whom and why ?	Strandby has a quite large fishing harbour with cooling demand. Therefore the original idea was to make a solar driven cooling system combined with district heating. During the design phase this system turned out as not economically feasible. The system was therefore changed and the absorption heat pump installed at the power plant cooling boiler fluegas and engine. The project concept was developed by Flemming Sørensen in cooperation with Flemming Ulbjerg (Rambøll) and Per Alex Sørensen / Ebbe Münster (PlanEnergi). The board of Strandby Varmeværk and an extra ordinary general assemblance had to be convinced. The details in the combination of a solar thermal plant and an absorption heat pump combined with a natural gas fired CHP-plant had to be developed.
Planning and Design Who made the planning and the design and why ?	The largest technological challenge was the control system, because the plant is operating on the electricity market. Thus a.o. • Content of accumulation tank • Forecast for solar production • Forecast for electricity prices • Forecast for electricity regulation market • Natural gas prices Has to be taken into account when running the system. In winter when the absorption heat pump is running, one accumulation tank serves as cold water tank. In summer both accumulation tanks serve as hot water tanks.
Tendering Lessons learned ..	The tendering was divided in 1. Solar collectors 2. Pipes in solar circuit 3. Accumulation tank with house for pumps, heat exchangers etc. 4. Pumps, heat exchangers and pipes inside the utility 5. Absorption heat pump 6. Control system The idea by dividing the solar system in 3 enterprises was to get a lower price. But the price was not lower than normal, and as a result there was more coordination work for the building owner compared to the situation with a total contractor taking care of 1-3 and part of 4, which until then had been the normal way in Denmark. Also the comparison between solar collectors was difficult, because the efficiency curve that normally is measured includes heat losses in pipes.

Construction Technologies, lessons learned	During the construction phase no major technological challenges had to be overcome. Of minor challenges can be mentioned that pipes in the solar collector circuit was not cleaned well. That has meant later problems with a.o. valves.
Commissioning Lessons learned ..	Commissioning took place in the winter 2009. That meant that it was necessary to regulate flows in a period with low production. This regulation had therefore to be corrected afterwards resulting in problems with pumps and a lower production in the first ½ year.
Operation Lessons learned ..	Also the control system was not fully implemented in the first period. After fully implementation of the control system all parts of the concept is now functioning as expected.
Performance Lessons learned ..	The performance of the solar collectors is slightly below expectations. The production was 3,50 GWh in 2009 and calculated production was 3,76 GWh. The performance of the absorption heat pump is as expected. The absorption heat pumps covers app. 5 % of the yearly production.
Lessons learned Major lessons	Main lessons are • as few enterprises as possible • be careful with cleaning of pipes in the solar circuit • commissioning has to wait until a period with large production • control system is the most difficult part and has to be closely supervised and delivering dates have to be connected to an economical penalty
Recommendations Major recommendations	It is recommended to find a more precise system to compare bits from collector entrepreneurs. In Strandby this was done by calculating production with measured efficiency curves in testlaboratories, but the result is very sensitive to insecurities in the measuring of efficiency curves – even at accredited test laboratories.
Others	Result can be seen at www.solvarmedata.dk

Photos	  

A3. Berliner Ring, AT

PLANT	
Name / Id	Berliner Ring Graz
Address	Berliner Ring 22 - 56, A-8047 Graz
Operation	since March 2004
Owner	Solar.nahwaerme.at
Contakt person Name, tel. e-mail	Moritz Schubert, m.schubert@solid.at +43 316 29 2840-81
Type Short description of the application	Roof mounted solar plant (2.417 m²) for domestic hot water and room heating of multifamily houses (350-500 m² collector area each) in a high-rise apartment area. Buffer storage of 60 m³ is installed.
Technical Basic data, type and dimensions, etc.	Heat load 21,4 TJ/year (7,84 GWh/year); Oekotech Gluatmugl large surface collectors; solar contribution 3,6 TJ/year (1 GWh/year, 100 % solar in summer); 2 water tanks for buffering (60 m³ capacity all over), installed in underground pump room. The solar plant feeds directly into the inhouse grid of the buildings on which the solar plant is mounted. Excess heat is supplied to the local grid of the housing area and two buffer storage of 30 m³ each. The low pressure local grid is connected to the city's DH grid via heat exchanger. Lower connection capacity (minus 20%) of local grid to district heating grid because of buffer storages. This generates savings every year and is used for payback of the solar plant. Remote control and care via data transmission.
Economics Basic data, investment, subsidies, solar heat cost (describe assumptions), etc	Total investment of approx. 1,25 Mio. EUR, partly covered by subsidies (around 40 %); The flats in the area are owned by the residents. As a joint investment of several hundred flat owners into the solar plant was not viable, energy service contracting was chosen for financing: solar.nahwaerme assigned S.O.L.I.D. to build the plant and is now the owner of the plant. Heat is sold at same price as the local district heating utility to the residents of the houses. Equivalent to fossil fuel tax (2009: 5 € per MWh_{th}) is also paid to solar.nahwaerme. The local grid is operated by a company of Energie Graz, the local utility. For buffering solar heat via the local grid to the buffer storage, a system usage fee has to be paid by solar.nahwaerme.

PLANT HISTORY	
Initiation Who initiated the plant and why ?	In 2003, the heat supply of the high-rise apartment area was switched from oil boilers to the city's district heating grid. Also other refurbishment works were done in 2003, e.g. roof renovation. S.O.L.I.D. was in contact with both the local utility and the housing company about starting an innovative large scale solar project in Graz. Many meetings with the involved companies and representatives of the flat owners took place. It was very convenient that Berliner Ring is in proximity to the private home of Christian Holter, CEO of S.O.L.I.D..
Support Describe possible national incentives to this type of applications	The plant was supported by Austria's federal government, region Styria and city of Graz.
Development How was the project developed, by whom and why ?	Starting point was roof renovation and upgraded insulation of the houses. This facilitated the erection of solar collectors on top of the roof. The flat owners, S.O.L.I.D., the house management and the local utility discussed all financial and technical matters thoroughly in advance of the construction works. S.O.L.I.D. developed the project and offered attractive economic conditions to the residents. S.O.L.I.D. also managed the public funding.
Planning and Design Who made the planning and the design and why ?	S.O.L.I.D. developed all technical systems related to the solar plant and the buffers as the company has many years of experience in planning, designing, constructing and maintaining of large scale solar plants.
Tendering Lessons learned ..	No major works were executed by sub-contractors.
Construction Technologies, lessons learned	The elevating frames of the solar collectors were directly connected to devices, which were integrated into the flat roof at renovation. The heat pipes from the roof to the ground were installed at the outside façade.
Commissioning Lessons learned ..	No major problems, as control equipment for the local grid had been installed years before and operational experience was existing.
Operation Lessons learned ..	Via remote control, the plant and buffer operation had to be optimized during first year of operation. One heat exchanger broke down.
Performance Lessons learned ..	According to expectations.
Lessons learned Major lessons	It is much more challenging to integrate an innovative large scale solar system into an existing heating system than installing an entire new system.
Recommendations Major recommendations	For such large and innovative projects it is crucial that all stakeholders are committed to the project and deliver contribution and support.

Edited by: Moritz Schubert, S.O.L.I.D.
Contributions from: Franz Radovic, S.O.L.I.D.

A4. Wasserwerk Andritz, AT

PLANT	
Name / Id	Wasserwerk Andritz
Address	Wasserwerkgasse 9-11, A-8045 Graz
Operation	From spring 2009 (3600 m² + 300 m² in spring 2010)
Owner	solar.nahwaerme Energiecontracting GmbH
Contakt person Name, tel. e-mail	Moritz Schubert, m.schubert@solid.at +43 316 29 2840-81
Type Short description of the application	Ground mounted solar plant (3855,1 m²) for domestic hot water and room heating of office building (water utility Graz AG) and for feed-in into district heating grid (Energie Graz GmbH, EGG). Buffer storage of 60 m³ is installed for solar plant and district heating (lower connected load).
Technical Basic data, type and dimensions, etc.	Heat load 2,88 TJ/year (800 MWh/year); Oekotech Gluatmugl high temperature collector (brut area mainly 14,3 m² each, smallest collector is 7,2 m²); collectors are sized and placed dependant on ground space and hydraulics; solar contribution 5,83 TJ/year (1,62 GWh/year); water tank for buffering (60 qbm), installed in former underground pump station of water works. The solar plant feeds into a buffer store with approx. 65 m³ as a matter of priority which serves as an inventory heat storage tank. In the case that the solar plant cannot deliver energy, the district heating as a conventional source of energy supplies the buffer store. Furthermore it is planned in the near future to install a heat pump, which comes to application depending on the requirements of the buffer store and dependent on the temperatures in the collector circle. Starting out from the buffer store the existing objects as well as the new building are provided with heat. If there is a surplus of solar energy, i.e. the buffer store is fully loaded and can take no more heat, the solar plants feeds directly into the district heating net of Energie Graz. By using the upper third of the buffer volume for buffering heating from district heating grid, the connected load could be lowered by 30%.
Economics Basic data, investment, subsidies, solar heat cost (describe assumptions), etc	Total investment of approx. 1,5 Mio. EUR, 30% covered by federal subsidy; Energy service contracting for 20 years: solar.nahwaerme sells heat at a competitive price to local fossil power plants to Energie Graz. Equivalent to fossil fuel tax (2009: 5 € per MWh_{th}) is also paid to solar.nahwaerme. On the other hand solar.nahwaerme sells the heat, either solar or from district heating grid, to water utility Graz AG for room heating at same price as district heating. The rates for district heating comprise an energy tax on fossil fuels of 5€/MWh. These 5 euro are also paid by Graz AG, but go to solar.nahwaerme and not to the treasury. The ground for the solar plant is provided by Graz AG.

PLANT HISTORY	
Initiation Who initiated the plant and why ?	An operation building with offices, laboratory, and further buildings as well as parking lots was located in the area of the water supply company in until 2008. Due to the strategic decision to concentrate the complete business unit of water supply at this location, a new building was built for the water supply company. In the course of the rearrangement of the location the client thought about a change from the previous energy supply by electricity to alternative sources of energy. The disadvantage of the present hot-water provision and room heating is the increasing price of electricity. The installed system arrived at the bound of its life time and showed correspondingly low efficiency. After an economic and ecological analysis of the heat demand for the existing and planned objects the client came to the decision to provide the future energy supply with a combination of solar energy, district heating and heat pump. The solar plant is operated in a contracting model. solar.nahwaerme Energiecontracting GmbH is the owner and operates of the plant. S.O.L.I.D. GmbH was in charge of design and planning.
Support Describe possible national incentives to this type of applications	The entire system of solar collectors, buffer, controls, piping, pump units etc. was subsidied by the Federal Ministry of Agriculture, Forestry, Environment and Water Management. Kommunalkredit Public Consulting (KPC) managed the funding in charge of the ministry. The funding was 30% percent of the total investment of 1.400.000 €.
Development How was the project developed, by whom and why ?	In 2006 S.O.L.I.D. GmbH and Energie Graz Gmbh founded Solar Graz GmbH. Energie Graz is co-owned mainly by the City of Graz and Styria region and expressed ambitious goals regarding solar energy. Solar Graz was founded in order to be the energy contracting service company for large scale solar thermal plants. One of the developed projects was Wasserwerke Andritz. In 2008, solar.nahwaerme replaced Solar Graz as ESCO for Wasserwerke Andritz.
Planning and Design Who made the planning and the design and why ?	Solid was in charge of the planning. As the plant is in a low level water protection area, special attention had to be paid on the leakage control system of the solar plant. This is realized both by pressure measurement within the pump unit and leakage alarm wires as common in district heating. In winter, the district heating grid operates on high pressures of 6-13 bar. This was measured beforehand in a control room near Wasserwerke Andritz. This high pressure requires high pumping power and has to be considered every time when surplus heat from the solar plant is available.
Tendering Lessons learned ..	Main parts and works were supplied by solid and Oekotech.
Construction Technologies, lessons learned	Considerable management efforts were taken as various lines and pipes for water, heating, electricity, glass fibre cables etc. are in the underground of Wasserwerke area and works and changes on these lines were done while construction of the solar plant and the heating system.
Commissioning Lessons learned ..	Problems in controls showed up as coordination between planning of the solar und buffer system and building technology of the new water utility office building was not perfect. Some parts had to be replaced.

Operation Lessons learned ..	Buffer management has to be optimized while operation.
Performance Lessons learned ..	The heat output of the solar plant is according to the expectations.
Lessons learned **Major lessons**	A change of major project partners can happen in course of the project.
Recommendations Major recommendations	Exact knowledge about all system parts and partners is essential before planning. E.g. what and when is the exact heat demand, which control systems are used, at which pressure does the district heating grid operate at which time.
Photo	

Edited by: Moritz Schubert, S.O.L.I.D.
Contributions from: Hannes Davic, S.O.L.I.D.

A5. Neckarsulm-Amorbach, DE

PLANT	
Name / Id	Solar District Heating Neckarsulm-Amorbach
Address	Grenchenstraße D-74172 Neckarsulm GPS 49.212406, 9.256411
Operation	Construction and pilot operation in two phases: Phase 1, 1997 to 2001: First pilot borehole thermal energy storage (BTES) with 4300 m³, first extension of BTES with 20000 m³, first collector fields with a capacity of 1.89 MW_{th} / 2700 m². Phase 2, 2001 to today: Extension of the BTES to 63000 m³ and the collector fields to 3.97 MW_{th} / 5670 m², installation of a heat pump with 521 kW_{th} in 2008.
Owner	Stadtwerke Neckarsulm (public utility) www.stadtwerke-neckarsulm.de
Contact person Name, tel. e-mail	Sigbert Effenberger Sigbert.effenberger@neckarsulm.de
Type Short description of the application	Solar district heating system with seasonal thermal energy storage backed-up by gas boiler plant and heat pump. Solar collectors are installed on buildings, carport and noise-protection wall. DH net provides space heating and domestic hot water to a new housing district with commercial activities, school, housing for elderly.
Technical Basic data, type and dimensions, etc.	Technical data actual 2010 Solar collectors: 3.97 MW / 5670 m² Seasonal thermal energy storage: 63000 m³ Buffer strorages: 2 x 100 m³ Heat pump: 521 kW_{th} Backup: gas condensing boiler Heated area: 25000 m² Heat demand: 3000 MWh/a Solar fraction: 46 % (2008) DH net return temp.: 46 °C (planned 35 °C)

Economics Basic data, investment, subsidies, solar heat cost (describe assumptions), etc	Cost of the SDH system*: 3.5 Mio € Solar heat cost**: 26.5 ct./kWh Assumptions: *excl. VAT and subsidies, incl. planning, status 5007 m² solar collector area and 63000 m³ BTES **calculated value for long term operation
PLANT HISTORY	
Initiation Who initiated the plant and why ?	SDH promoters convinced local political decision makers and stakeholders.
Support Describe possible national incentives to this type of applications	Funding by: - German national R&D programme Solarthermie 2000 / Solarthermie2000plus - Ministry of Economics of Baden-Württemberg - City of Neckarsulm - European Concerto Programme General funding approach: The funding level is approx. 50 %.
Development How was the project developed, by whom and why ?	The project was developed by Stadtwerke Neckarsulm, the city of Neckarsulm and Steinbeis Transferzentrum EGS on the basis of a resolution of the City Council.
Planning and Design Who made the planning and the design and why ?	The whole system, the BTES and the collector fields were planned by Steinbeis Transferzentrum EGS and EGS-plan. Technical innovations and challenges were: - The BTES was Europe-wide the largest and first of its kind. - A three-pipe DH distribution net with decentral heat transfer units between solar and DH net was developed and realised. - Various innovative collector field installation and integration technologies (solar roof, on carport, on bearing structure of the gym) In detail: - System integration of the BTES without heat exchangers for increasing the overall system performance - Investigations on oxygen entry through the borehole heat exchangers (BHE) - Polybuten double-U-BHE in betonite-sand-cement grouting material - Development of the collector field size was driven by the construction of buildings. The BTES size was adapted to the collector field size. - cooperative financing of one collector field on a carport
Tendering Lessons learned ..	In general normal tendering procedures were followed. For some special components, the number of suppliers and service providers were limited.

Construction Technologies, lessons learned	Constructions were carried out following the phases as described above. History: 1997: Collector fields on school, gym, shopping centre, home for elderly (2636 m²) 1997: Pilot stage of BTES (36 ducts, 4300 m³) 1999: First stage of BTES (168 ducts, 20000 m³) 2000: Collector field on carport (454 m²) 2001: Collector field on row houses (808 m²) 2001: Second stage of BTES (528 ducts, 63000 m³) 2002: Collector field on noise protection wall (1109 m²) 2004: Collector field on residence for elderly (256 m²) 2008: Installation of heat pump Following experiences were made: - The installation method for the borehole heat exchangers (BHE) was improved making use of long tables and a crane. Nowadays, BHE are unrolled from coils. - The building pit ground was paved with drainage gravel what significantly facilitated installation works and traffic of machines. - Construction and modification of solar system elements should be carried out in fall or winter in order not to disturb the functionality of the solar heat system under charging conditions. - Settlements of the soil resulted in the distortion of the collector fields on the noise protection wall. The ground had to be redensified and the panels adjusted anew. Foils against plant growth underneath the panels were added.
Commissioning Lessons learned ..	The control system required an extended commissioning phase.
Operation Lessons learned ..	Operation showed that the performance of a SDH with BTES is particularly sensitive to elevated DH net return temperatures. The integration of a heat pump significantly improves the system robustness and performance.
Performance Lessons learned ..	Annual energy balances are available starting from 1997. In 2008, total heat load and useful solar heat appr. match design assumptions. Since 2005, solar fractions over 40 % are reached compared to the design value of 50 %. BTES: Heat transmission in BHE is less than expected because of low heat conductivity of the utilized filling material in BHE The heat capacity of the ground turned out to be slightly higher than expected resulting in a higher storage capacity. The buffer stores improve the performance of the BTES and compensate its limited charge and discharge capacity.

	The heat pump improves the whole system performance and compensates the high sensitivity of a SDH with BTES to elevated DH net return temperatures. Effect of additional heat pump to be evaluated in 2010 after the first year of operation. The solar heat exchangers only reach about 85-90 % of the expected heat exchange performance.
Lessons learned Major lessons	Valuable experiences could be gained related to the planning, construction and operation of a large BTES. The performance of a SDH with BTES is particularly sensitive to elevated DH net return temperatures. The integration of a heat pump significantly improves the system performance. The application of the three-pipe DH distribution net did not lead to major cost reductions and performance improvements. The SDH systems could be very well integrated into the local urban environment.
Recommendations Major recommendations	Further improvement of the BTES design (hydraulic connection of BHE, construction of thermal insulation, evaluation of alternative BHE materials) Integration of an adequate buffer volume to improve BTES performance and reduce required borehole length. Integration of a heat pump into SDH systems with BTES Evaluation of the benefits of a three-pipe DH distribution net
Others	www.saisonalspeicher.de

A6. Crailsheim, DE

PLANT	
Name / Id	Solar District Heating Crailsheim Hirtenwiesen
Address	Residential area Hirtenwiesen D-74564 Crailsheim
Operation	Operation start of the ‘first milestone’ in 2005
Owner	Stadtwerke Crailsheim (public utility) www.stw-crailsheim.de
Contact person Name, tel. e-mail	Jürgen Hübner info@stw-crailsheim.de
Type Short description of the application	Solar district heating system with seasonal thermal energy storage backed-up by small district heating net and heat pump. Solar collectors are installed on new and renovated buildings and a noise protection wall. DH net provides space heating and domestic hot water to a new housing area, renovated multi-family houses (in total 260 housing units), a school and a gym. The area is developed within a conversion programme for a former military area.
Technical Basic data, type and dimensions, etc.	Technical data actual 2010 / final Solar collectors: actual / final — 5.1 / 6.8 MW_{th}; 7300 / 9700 m² Seasonal thermal energy storage: 37500 / 75800 m³ Borehole Thermal Energy Storage (BTES) Buffer strorages: 100 and 480 m³ Heat pump: 350 / 2 x 350 kW_{th} Backup: small district heating net Heat demand: 4100 / 7000 MWh/a Solar fraction: 50 % (design)
Economics Basic data, investment, subsidies, solar heat cost (describe assumptions), etc	Total investment cost: 7 Mio € Funding*: 3.4 Mio € Solar heat cost**: 19 ct./kWh Assumptions: *by Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and Ministry for Economics of Baden-Württemberg **calculated value for long term operation, 6 % interests

PLANT HISTORY	
Initiation Who initiated the plant and why ?	SDH promoters convinced local political decision makers and stakeholders.
Support Describe possible national incentives to this type of applications	Funding by: - Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (German national R&D programme Solarthermie 2000 / Solarthermie2000plus) - Ministry for Economics of Baden-Württemberg - City of Crailsheim General funding approach: The funding level is approx. 50 %.
Development How was the project developed, by whom and why ?	The project was developed by Stadtwerke Crailsheim, technical designers and Solites.
Planning and Design Who made the planning and the design and why ?	Planning services were tendered. System planning by HGC GmbH Hamburg BTES storage planning by Kohlsch Buffer storage planning by Ing.-Büro Lichtenfels Challenges were: - improvement of the BTES design (PEX probe material, hydraulic connection of probes, extendibility of BTES, BTES insulation) - complicated and long process for obtaining the hydro-geological building permission for the BTES - technical solution for handling of a minor water flow in the upper BTES level - cost-effective buffer store design based on pressurized concrete stores with stainless steel liners, safety concept for the stores, stratification devices, insulation of the stores based on foam glass granulate and liners - overall system optimisation, integration of the heat pump, direct hydraulic integration of storages without heat-exchangers - integration of collector field on multi-family houses including roof windows and balconies - cost reduction of the supporting framework for the collectors on the noise protection wall - ecological landscape integration concept for the collectors on the noise barrier wall
Tendering Lessons learned ..	In general, normal tendering procedures were followed. For some special components, the number of suppliers and service providers were limited. For the first time planning services were tendered (see above)
Construction Technologies, lessons learned	History: 1999: Urban development plan for former US military area. 2000: Feasibility study by Steinbeis Transferzentrum EGS and Stadtwerke Crailsheim 2001: Decision by the city council, total cost 7 Mio. €

	2003: Start of system planning 2004: Site development for the building area 2005: Operation of the ‘first milestone’: 1.1 MW_{th} / 1500 m² of solar collectors on buildings and 100 m³ buffer store 2007: Construction of the second buffer store with 480 m³ and 2.5 MW_{th} / 3500 m² solar collectors on the noise protection wall 2008: Construction of the BTES (1^{st} phase) with 37500 m³ and additional 280 kW_{th} / 400 m² solar collectors on buildings 2010 (planned): Installation of the heat pump with 350 kW_{th} 2010 (planned): Extension of the collector area to 7300 m² Following experiences were made: - A next generation design and construction process of the BTES was developed. - Collectors supplied by one manufacturer were not suitable for large collector field installation.
Commissioning Lessons learned ..	The control system required an extended commissioning phase.
Operation Lessons learned ..	The BTES was charged for the first time in 2009.
Performance Lessons learned ..	So far no performance data are available for the overall system.
Lessons learned Major lessons	Valuable experiences could be gained by the construction of a next generation BTES and innovative buffer stores. The overall system efficiency could be improved. Improved solar collector integration into buildings and landscape could be demonstrated.
Recommendations Major recommendations	Replication of the cost-effective BTES and buffer store concepts. System integration of a heat pump for the discharging of the BTES.
Others	www.saisonalspeicher.de

Photos	  

A7. Vislanda, SE

PLANT	
Name / Id	Vislanda 17:13 eller Björken
Address	Storgatan 28-32, Vislanda
Operation	Late 2009
Owner	Allbohus Fastighets AB (Municipal housing Ass.)
Contakt person Name, tel. e-mail	Lennart Lindstedt, Allbohus <lennart.lindstedt@allbohus.se> Gunnar Lennermo, Energianalys AB <gunnarl@energianalys.net> Bengt Carlsson, Alvesta Energi AB
Type Short description of the application	Roof-integrated FP collectors on one existing multifamily building. The solar system is connected to the local district heating system in Vislanda. The housing association has a net-metering contract with the district heat supplier (Alvesta Energi AB).
Technical Basic data, type and dimensions, etc.	A multifamily building with 1 069 m^2 of heated area, annual heat demand of about 150 MWh and an annual water usage of about 1 500 m^3. A traditional design a solar heating system would result in a rather small plant. The building is equipped with a roof to be refurbished and the south facing roof area is about 400 m^2. The solar collector array comprises about 350 m^2 of large module solar collectors. The expected heat output is of the order of 140 MWh/a. The solar collector roof is connected to the district heating network via a pre-fabricated sub-station incl. heat exchangers, expansion, pumps, controls, etc.
Economics Basic data, investment, subsidies, solar heat cost (describe assumptions), etc	**Site specific inv cost in € incl. VAT** Contract solar system 223 000 (April, 2009) Roof renovation - 34 000 Subsidy - 43 000 Net solar system cost 146 000 incl. VAT **General inv cost in € excl. VAT** Contract solar system 178 000 (April, 2009) Subsidy -43 000 Net solar system cost 135 000 excl. VAT Estimated heat output 138 000 kWh/a Specific inv cost incl. VAT 1.06 €/kWh/a General inv cost excl. VAT 0.98 €/kWh/a **Solar heat cost with annuity 0.05 0.10** Specific incl. VAT 0.05 0.11 €/kWh General excl. VAT 0.05 0.10 €/kWh

PLANT HISTORY	
Initiation Who initiated the plant and why ?	Allbohus was interested to apply solar heating systems in their buildings. Initial discussions led to investigations concerning a direct connection to the existing district heating system using roof-integrated collectors on the roof (to be refurbished).
Support Describe possible national incentives to this type of applications	Investment grant amounting to 2.50 SEK/kWh annual collector (label) output up to 3 million SEK per project.
Development How was the project developed, by whom and why ?	Energianalys AB (consultant) was contracted by Allbohus to make a preliminary design and develop call for tenders. The proposed project was presented to the board for decision.
Planning and Design Who made the planning and the design and why ?	Energianalys AB, who had previous experience from similar plants.
Tendering Lessons learned ..	Separate tendering for collectors on roof and system connection to DH. Evaluation resulted in one contractor taking on all parts (managed sub-contractors for collectors, hx and installation).
Construction Technologies, lessons learned	Standard Swedish flat plate collectors. Pre-fabricated sub-station (heat exchanger incl. pumps and controls).
Commissioning Lessons learned ..	The commissioning went OK, except for some pressure sensors that will be replaced. A general observation is that there is a need to educate ordinary commissionaires to enable better commissioning of solar heating plants.
Operation Lessons learned ..	The control is available on internet via a modem. This has been of great value to overlook the operation during the first months.
Performance Lessons learned ..	Ongoing evaluation during 2010.
Lessons learned Major lessons	Small and handy system, large interest from housing owner as well as energy utility, a couple of appropriate tenders.
Recommendations Major recommendations	Valuable to carry out feasibility study and get a broad support for the plant. The need for refurbishment of the roof makes the collector installation more interesting from an economic point of view. The system comprises well established products, which makes everything much easier. The internet access is of great value.

Photos	
	

A8. Hotel DUO, CZ

PLANT	
Name / Id	Hotel DUO – Prague
Address	Teplická 19, 190 00 Praha
Operation	2007
Owner	Mr. Jan Horal – owner of the hotel
Contakt person Name, tel. e-mail	Ing. Vít Mráz – Tronic Control s.r.o. (contractor of the system) mraz@tronic.cz, +420 266 710 254
Type Short description of the application	Heat from evacuated tube collectors which are situated on the roof of the hotel is used for cooling (absorption cooling unit) and for hot water production. Heat from collectors is accumulated in short term water storages that have about 16 m^3.
Technical Basic data, type and dimensions, etc.	Total heat load from collector array is 0,270 GWh/year. 61 % of total amount of heat is used in absorption unit for cooling. Collector array is built of 282 evacuated tube collectors, that have 535,8 m^2. Solar fraction is about 66 % for cooling. Fraction of the rest of solar heat which is used for hot water preparation is not known. Rated output of the absorption unit is 560 kW. Chilled water is accumulated in two stainless tanks that have 4 m^3. As an additional source of heat is used heat exchanger station connected to the district heating system. Total rated output of four used heat exchangers is 1250 kW. As a backup heat source, are used six boilers (natural gas) connected into the cascade with a total output of 480 kW.
Economics Basic data, investment, subsidies, solar heat cost (describe assumptions), etc	Costs of the cooling systems with absorption unit were about 320 000 EUR and any subsidy program was not used.

PLANT HISTORY	
Initiation Who initiated the plant and why ?	The cooling system was realized due to the needs resulting from the hotel status (4*). Certain liberality of the owner and low available electric performance in hotel location caused the choosing of the final solution using solar heat.
Support Describe possible national incentives to this type of applications	Solar thermal systems in the business sector are supported from the program called EKO-ENERGY provided by the Ministry of Industry. It is possible to get 30 % of eligible costs connected to solar system installation. Unfortunately solar systems has low priority in the program so you cannot be sure that you will get support because the total amount of money is limited and preferably are supported projects with higher priority.
Development How was the project developed, by whom and why ?	Hotel owner decided to install cooling system. After some consultations and due to mentioned border conditions he has chosen a solution concerning solar system. Some influence played a positive relationship with the RES and experience acquired abroad.
Planning and Design Who made the planning and the design and why ?	The main contractor was the firm Tronic Control Ltd. They have designed and built the system but of course they cooperated with some other subjects. Study of solar system was made by experts from CTU in Prague.
Tendering Lessons learned ..	-
Construction Technologies, lessons learned	It is the largest collector array with evacuated tubes in Czech Republic so main contractor decided to make study which solved connection and regulation of collectors. For regulation of flow in collectors was used pump with variable speed.
Commissioning Lessons learned ..	Commonly components as collectors, absorption unit etc. are used in the system.
Operation Lessons learned ..	The main challenge was to set the operational parameters of quite complex system with three heat sources.
Performance Lessons learned ..	After three years in operation the solar fraction of cooling is still about 60 % and that in fact corresponds expectations.
Lessons learned Major lessons	It is possible to use solar heat for cooling also in Czech Republic, but there is a line of boundary condition, that must be met together. Enlightened investor, cheap heat from district heating as a additional heat source, lack of electricity in location of building, adequate needs of cooling etc.
Recommendations Major recommendations	Good example of a typical system that is useful because it was adapted to local conditions.

Photos	  

	

A9. Cost Tables

The sample plants presented here are built in different countries under different circumstances. Here it is the intention to present costs in a uniform way and describe the differences. The elaborated cost data are presented in the following two tables (A and B).

The sample plants comprise six rather large plants, with collector areas ranging from low 2 400 to high 8 020 m^2 of solar collectors and two rather small plants with about 400 m^2 of collectors built on two specific buildings.

The specific solar investment costs vary from low 205 €/m^2 collector area (large ground mounted collector array with diurnal storage) to high 959 €/m^2 collector area (roof integrated collectors and seasonal storage). The annual net solar heat gains vary from low 265 kWh/m^2 (seasonal storage) to high 504 kWh/m^2 (diurnal storage), while the solar coverage (solar fractions) vary from high 50% (seasonal storage) to only a few % for those plants connected in a large district heating network.

The solar heat cost is calculated using the annuity method based on total investment cost and annual net solar heat gains. Annuity factors for different combinations of interest rate and depreciation times are given below, where 0.064 (4% and 25 years depreciation) has been chosen for the comparison. It goes without saying that a solar heating system is an investment and that the feasibility is favoured by low interest rate and long depreciation time.

Rate	**2%**	**4%**	**6%**	**8%**
Year				
15	0.07783	0.08994	0.10296	0.11683
20	0.06116	0.07358	0.08718	0.10185
25	0.05122	**0.06401**	0.07823	0.09368
30	0.04465	0.05783	0.07265	0.08883

All plants except one have subsidies of some kind. The value of the subsidy varies from low 20% to high 50% of the total investment cost. The resulting solar heat cost, from low 31 to high 219 €/MWh (25 and 119 incl. subsidies), can be compared with the alternative cost, low 40 to high 60 €/MWh, for generating the corresponding amount of heat by the present alternative.

Large solar heating systems have the advantage of scale and often show lower specific investment costs and solar heat costs than systems for small buildings. This advantage is to some extend compensated by the fact that they have to compete with alternatives, i.e. district heating, which also utilizes the advantage of scale.

Here it is interesting to note that even with a very small number of large scale solar heating systems (about 1% of total installed collector area in Europe) a number of these plants already compete with traditional alternatives. A greater interest and/or improved support and marketing, and thereby a larger market for large solar heating systems, would of course result in even lower investment costs.

Table A

Two central solar district heating plants with ground mounted collector arrays for existing buildings (DK).

1. Strandby – Solar heat in combination with natural gas CHP and boilers.
2. Brædstrup – Same as above.

Two local solar district heating plants, one with collectors mounted on existing buildings one with ground mounted collectors, in a large district heating system in Graz (AT).

3. Berlinger Ring – Solar heat in combination DH.
4. Andritz - Same as above.

Plant id	**1. Strandby**		**2. Brædstrup**		**3. BerlinerRing**		**4. Andritz**		**Unit**
Country	DK		DK		AT		AT		
Year	2008		2007		2004		2009		
Collectors on	Ground		Ground		Roof		Ground		
Storage type	DS		DS		DS		DS		
Solar collectors	1 440		incl.		700		1000		1 000 €
Solar coll area		***8 019***		***8 000***		***2 400***		***3 855***	**m²**
Spec coll. cost		*180*				*292*		*259*	€/m²
Pipes coll. etc.	160		incl.		220		300		1 000 €
Storage	410		No		80		100		1 000 €
Storage volume		*1 500*				*60*		*60*	m³
Spec storage cost		*273*				*1333*		*1 667*	€/m³
HX pumps etc	130		incl.		incl.		incl.		1 000 €
Controls	40		incl.		50		50		1 000 €
Design	140		incl.		200		150		1 000 €
Total cost excl VAT	**2 320**		**1 640**		**1 250**		**1 600**		**1 000 €**
Spec total cost		*289*		*205*		*521*		*415*	€/m²
Heat load	21 000		42 000		7 800		(DH)		MWh/a
Net solar heat	**3 500**		**3 400**		**1 000**		**1 620**		**MWh/a**
Spec net solar heat		*436*		*425*		*417*		*420*	kWh/m²
Solar percent		*17%*		*8%*		*13%*			
Spec cost	0,66		0,48		1,25		0,99		€/kWh/a
Annuity	0,064		0,064		0,064		0,064		-
Solar heat	**42**		**31**		**80**		**63**		**€/MWh**
Subsidy	480		320		500		480		1 000 €
Subsidy percent		*21%*		*20%*		*40%*		*30%*	
Total cost incl sub	1 840		1 320		750		1 120		1 000 €
Spec cost incl sub	0,53		0,39		0,75		0,69		€/kWh/a
Solar heat incl sub	**34**		**25**		**48**		**44**		**€/MWh**
Alternative cost *)	40		40		54		49		€/MWh

*) The actual cost for heat that the solar heat will replace / compete with ..

SDH solar district heating

Table B

Two central solar district heating plants with roof integrated collectors and seasonal storage for two new building areas (DE).

5. Neckarsulm – Solar heat (50%) in combination with natural gas boilers (50%).
6. Crailsheim – Same as above.

Two small local solar district heating plants, both with collectors mounted on existing buildings, one connected to DH (SE), one for cooling and hot water in a hotel (CZ).

7. Vislanda – Solar heat in combination with DH.
8. Hotel DUO – Solar cooling (and heating) in combination with NG boilers and DH.

Plant id	**5. Neckarsulm**		**6. Crailsheim**		**7. Vislanda**		**8. Hotel DUO**		**Unit**
Country	DE		DE		SE		CZ		
Year	1997-2007		2005-2009		2009		2007		
Collectors on	Roof		Roof		Roof		Roof		
Storage type	SS+DS		SS+DS		xS		DS		
Solar collectors									1 000 €
Solar coll area		***5 670***		***7 300***		***345***		***536***	**m²**
Spec coll. cost									€/m²
Pipes coll. etc.					incl.				1 000 €
Storage					No				1 000 €
Storage volume									m³
Spec storage cost									€/m³
HX pumps etc					incl.				1 000 €
Controls					incl.				1 000 €
Design									1 000 €
Total cost excl VAT	**3 500**		**7 000**		**178**		**320**		**1 000 €**
Spec total cost		*617*		*959*		*516*		*597*	€/m²
Heat load	3 000		4 100		(DH)		(SHC)		MWh/a
Net solar heat	**1 500**		**2 050**		**138**		**270**		**MWh/a**
Spec net solar heat		*265*		*281*		*400*		*504*	kWh/m²
Solar percent		*50%*		*50%*					
Spec cost	2,33		3,41		1,29		1,19		€/kWh/a
Annuity	0,064		0,064		0,064		0,064		-
Solar heat	**149**		**219**		**83**		**76**		**€/MWh**
Subsidy	1 750		3 400		43		0		1 000 €
Subsidy percent		*50%*		*49%*		*24%*		*0%*	
Total cost incl sub	1 750		3 600		135		320		1 000 €
Spec cost incl sub	1,17		1,76		0,98		1,19		€/kWh/a
Solar heat incl sub	**75**		**112**		**63**		**76**		**€/MWh**
Alternative cost *)	50		50		60				€/MWh

*) The actual cost for heat that the solar heat will replace / compete with ..